# SEISMIC PERFORMANCE OF HISTORICAL FAÇADE ELEMENTS – HAZARD ASSESSMENT

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## INTRODUCTION

The conservation of built heritage represents a special area of expertise for civil engineers as well as for restorers. In Vienna, more than 25% of all existing buildings are more than a hundred years old. As a requirement for structural changes to these objects, a reassessment of the existing supporting structure is inevitable in many cases. Due to the risk-based design concept of ÖNORM B 1998-3 and forthcoming B 4008-1 for existing buildings, the awareness for a subsequent earthquake-proof redesign of 19$^{th}$ century buildings was raised in Austria [1]. Yet the consideration of historical façade elements is often neglected [2]. However, in the case of past earthquakes, it has been shown that these nonstrucutral components (NSCs) make up a substantial part of the observed building damages and, in the event of failure, they constitute a significant danger to persons.

## PROBLEM DEFINITION

Since the first formal mention about the seismic design of NSCs in the publication of the ATC-03 Report in 1978 [3], slightly different simplified design methods are defined in valid standards at the international level (e.g ASCE-7 [4], EC-8 [5] and DIN [6]) to calculate an inertial horizontal force to design NSCs. Figure 1 shows the respective transmission of the peak ground acceleration (PGA) in case of resonance for a typical historical 5-storey building.

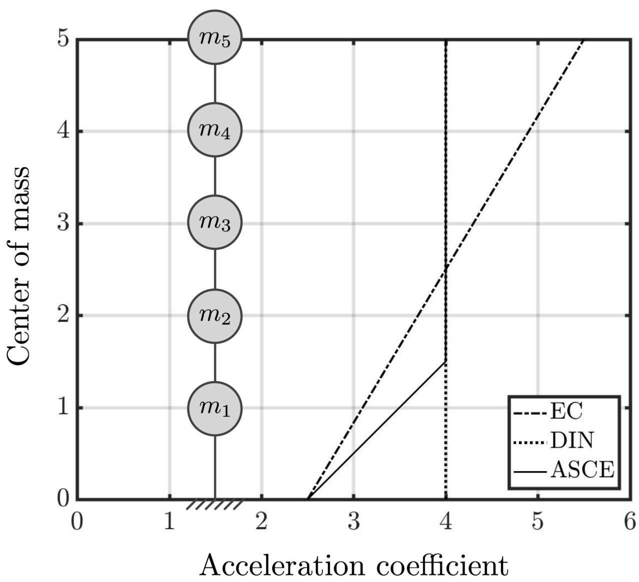


**Figure 1:** Transmission of the PGA for a 5-storey building in the resonance case – Consideration of selected standards

The application of such simplified methods is not universally valid for all different types of construction [1]. On the one hand, resonance effects are only taken into account with the first mode of the primary structure. If resonance occurs with the second mode, the design forces are underestimated. On the other hand, these simplified standards are just linear methods. This means that if nonlinear material behavior occurs, forces are likely to be overestimated. Numerous research projects have shown that the energy dissipation of the primary structures has a considerable influence on the resultant inertial design forces. In addition to assessing design loads, the prediction of local failure mechanisms of historical NSCs is another challenge, because the provisions of valid standards are primarily concerned with the design of their connections [3]. For these reasons, simplified approaches are often only adequate for a quick pre-design [7].

## RESEARCH OBJECTIVES AND METHODOLOGY

Comprehensive numerical simulations are being carried out to determine the maximum peak floor accelereation (PFA) for typical old Viennese masonry buildings, which depends on the PGA and the seismic response of the structure. Therefore, a specially calibrated material model for old masonry walls under cyclic loading is going to be applied in order to take specific failure mechanisms [8] into account. In the future it should be possible to use these determined limit values of the PFA for a suitable assessment, because detailled time history analysis in any individual case is associated with high effort. The next goal is gaining knowledge about the seismic performance and the specific failure mechanisms of typical historical façade elements. For this purpose, model experiments on a one-dimensional shaking table with representative test specimens will be conducted to examine the seismic behavior and the limit state. Figure 2 shows the developed test setup. Finally, the results of the model experiments will be evaluated with non-destructive in situ tests.

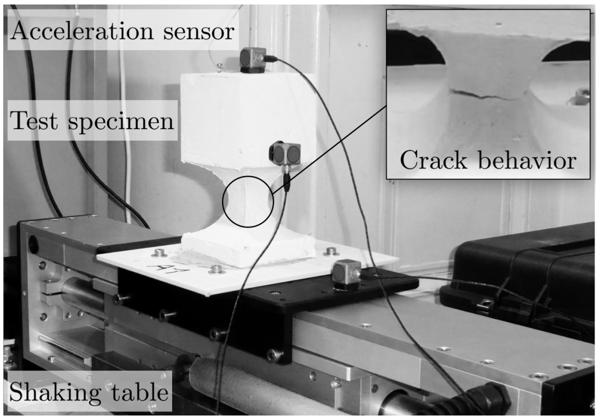


**Figure 2:** Setup for the limit state test

## CONCLUSION

The challenge of the seismic stabilization of historic façade elements is to find an acceptable balance between vulnerability and intervention that reduces the risk of damage [1]. The selection of suitable preventive measures often includes the evaluation of many possibilities. Strengthening such elements to survive future earthquakes might be technically possible, but it involves high costs and often an unacceptable intervention on the built heritage. The assessment depends essentially on the quality of the design parameter identification. The objectives of this research project are to determine design loads on historical façade elements as well as to estimate their seismic performance and limit state. Thereby sustainable and secure retrofitting should be possible in near future.

## REFERENCES

[1] Rudisch, A.; Dunjic, V.; Kolbitsch, A.: Historische Zierelemente unter Erdbebenbeanspruchung – State of the Art. Bauingenieur 91, p. 14-22, 2016

[2] Kolbitsch, A.: Assessment and retrofitting of façade elements of 19$^{th}$ century buildings. 15 WCEE Lisboa, 2012.

[3] Singh, M.P.; Moreschi, L.M.: Simplified methods for calculating seismic forces for nonstructural components. ATC-29-1 Seminar Technical Papers, 1998

[4] ÖNORM EN 1998-1: Eurocode 8: Auslegung von Bauwerken gegen Erdbeben - Teil 1: Grundlagen, Erdbebeneinwirkungen und Regeln fr Hochbauten (konsolidierte Fassung). Austrian Standards, 2013

[5] ASCE 7-10: Minimum Design Loads for Buildings and other Structures. ASCE, 2010

[6] DIN EN 1998-1/NA: Nationaler Anhang - National festgelegte Parameter - Eurocode 8: Auslegung von Bauwerken gegen Erdbeben - Teil 1: Grundlagen, Erdbebeneinwirkungen und Regeln für Hochbauten. Deutsches Normungsinstitut, 2011

[7] Moschen, L.; Adam, C; Vamvatsikos, D.: A response spectrum method for peak floor acceleration demands in earthquake excited structures. Probabilistic Engineering Mechanics Vol. 46, p. 94-106, 2016

[8] Dunjic, V.; Rudisch, A.; Kolbitsch, A.: The two-shearfield test – A suitable method for the empirical shear capacity design of masonry. Mauerwerk 20, p. 381-387, 2016